U.S. Department of Energy
Office of Environmental Management
(DOE-EM)

Engineering & Technology Roadmap

Reducing Technical Risk and Uncertainty in the EM Program

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Draft

1.0 INTRODUCTION

The U.S. Department of Energy's Office of Environmental Management (DOE-EM) was established in 1989 to achieve the safe and compliant disposition of legacy wastes and facilities from defense nuclear applications. A large majority of these wastes and facilities are 'one-of-a-kind' and unique to DOE. Many of the programs to treat these wastes have been 'first-of-a-kind' and unprecedented in scope and complexity. This has meant that many of the technologies needed to successfully disposition these wastes were not yet developed or required significant re-engineering to be adapted for DOE-EM's needs. Thus, throughout its existence, DOE-EM has required a strong technology component – focused on developing technologies to enhance safety, effectiveness, and efficiency – to accomplish its mission.

Although the Department has made great progress toward safely disposing of the legacies of the Cold War (e.g., the cleanup of the Fernald, Rocky Flats, and Mound sites), much remains to be done. While past accomplishments often provide a guide for future success, the unique nature of many of the remaining challenges will require a strong and responsive applied research and engineering program. To address this need, DOE-EM has established the ***DOE-EM Engineering & Technology Program.***

This document, prepared in response to Congressional direction, will be used to guide the ***Program.*** In the FY2007 House Energy and Water Development Appropriations Report, the Department was directed to 'prepare an EM technology roadmap that identifies technology gaps that exist in the current program, and a strategy with funding proposals to address them.' This report discusses the current technology risks and the strategies to address those risks.

2.0 PROGRAM OBJECTIVE, RISKS, and STRATEGIC INITIATIVES

The objective of the ***DOE-EM Engineering & Technology Program*** is to reduce the technical risk and uncertainty in the Department's clean-up programs and projects. Risks are known technical issues that could prevent project success. Uncertainties are indefinite or unpredictable technical aspects of a project. To reduce those risks and uncertainties, the ***Program*** will provide technical solutions where none exist, improved solutions that enhance safety and operating efficiency, or technical alternatives that reduce programmatic risks (cost, schedule, or effectiveness). The roadmap for this ***Program*** is provided in this document and identifies:

- The engineering and technical risks the DOE-EM program faces over the next ten years;
- The strategies DOE-EM will use to minimize these risks; and
- The planned outcomes of implementing those strategies.

The technical risks are identified in three ways:

<u>By the projects</u> - DOE-EM's operations are performed within a culture of disciplined project management, based on DOE Order 413.3A, *Program and Project Management for the Acquisition of Capital Assets*. As such, technical risks and uncertainties affecting each cleanup project are identified early in the project life-cycle, are captured in Project Risk Assessments, and often lead to applied technology development activities.

<u>By programmatic and external technical reviews</u> - DOE-EM utilizes experts to review the progress of its major cleanup projects. These reviews transcend the project's baseline, and often identify opportunities for reducing technical risk through development and deployment of innovative or enhanced technologies.

DOE-EM is also the subject of external reviews. In particular, the National Academy of Sciences (NAS) is reviewing the ***Program*** in 2007. The NAS will identify technology gaps and provide technical and strategic advice to support further development of this Roadmap.

<u>By the sites</u> - DOE-EM periodically asks the DOE sites to identify technical risks and uncertainties in the form of 'technical needs.' This was most recently completed at a workshop in October 2006.

After the workshop, the sites' needs were combined with risks and uncertainties that the other sources identified. The result is the set of technical risks identified in Table 1. The risks are divided into three primary program areas: Waste Processing, Groundwater and Soil Remediation, and Deactivation and Decommissioning (D&D) and Facility Engineering.

Also shown in Table 1 are the strategic initiatives that address each technical risk and uncertainty in the DOE-EM program. These strategic initiatives form the core of the ***DOE-EM Engineering & Technology Program***. These initiatives are expected to produce solutions for application at each of the DOE sites facing the same risk.

Table 1 – Summary of DOE-EM Technical Risks and Strategic Initiatives

Program Area	Technical Risk and Uncertainty	Strategic Initiatives
Waste Processing	***Waste Storage*** • Existing tanks provide limited storage and processing capacity, have exceeded their original design life, and will likely be in service for extended periods of time. • Conservative assumptions regarding behavior of waste during storage, such as flammable gas generation, restrict operations and increase costs.	***Improved Waste Storage Technology*** • Develop cost effective, real-time monitoring of tank integrity and waste volumes to ensure safe storage and maximum storage capacity. • Improve understanding of changing waste chemistry, including flammable gas generation, retention, release, and behavior to eliminate conservative assumptions in safety analyses.
	Waste Retrieval • Current waste removal and retrieval operations and monitoring technologies are costly, sometimes inefficient, and are limited by complicated internal tank design (e.g., obstructions) and conditions (e.g., past leak sites).	***Reliable & Efficient Waste Retrieval Technologies*** • Develop optimization strategies and technologies for waste retrieval that lead to successful processing and tank closure. • Develop a suite of demonstrated cleaning technologies that can be readily deployed throughout the complex to achieve required levels of removal.
	Tank Closure • Achieving acceptable levels of residual radioactivity in tanks and immobilization of residual material suitable for final closure has not been fully demonstrated. • Final closure of a waste management area, including closure of ancillary equipment such as underground transfer lines and valve boxes, has not been fully demonstrated.	***Enhanced Tank Closure Processes*** • Improve methods for characterization and stabilization of residual materials. • Develop cost-effective and improved materials (e.g., grouts) and technologies to efficiently close complicated ancillary systems. • Perform integrated cleaning, closure, and capping demonstrations.
	Waste Pretreatment • Achieving effective separation of low- and high-level wastes (HLW) prior to stabilization requires improved, engineered waste processes and more thorough understanding of chemical behavior.	***Next-Generation Pretreatment Solutions*** • Develop in- or at-tank separations solutions for varying tank compositions and configurations. • Improve methods for separation to minimize the amount of waste processed as HLW.
	Stabilization • Waste loading (i.e., the amount of waste concentrated in waste containers) constraints limit the rate that HLW can be vitrified, and the tanks closed. • Current vitrification techniques may require supplemental pretreatment to meet facility constraints.	***Enhanced Stabilization Technologies*** • Develop next-generation stabilization technologies to facilitate improved operations and cost. • Develop advanced glass formulations that simultaneously maximize loading and throughput. • Develop supplemental treatment technologies.
Groundwater and Soil Remediation	***Sampling and Characterization*** • Current sampling techniques and characterization technologies result in costly, time-consuming characterization programs, may leave large gaps in plume delineation, and may lead to selection of inappropriate or inadequate cleanup strategies. • Incomplete understanding of contaminant subsurface behavior results in long-term uncertainty regarding risks to human health and the environment.	***Improved Sampling and Characterization Strategies*** • Develop advanced sampling and characterization technologies and strategies for multiple contaminants (organics, metals and radionuclides) in challenging environments (e.g., around subsurface interferences, at great depth, in low permeability/porosity zones, etc). • Use basic and applied research to gain a better understanding of contaminant behavior in the subsurface and to provide defensible prediction of risk.
	Modeling to Guide Cleanup • Current models do not adequately represent complex hydrogeology, biogeochemistry, chemical reactions, and transport. Thus, under complex subsurface conditions, the models may not adequately predict contaminant fate and transport or provide a sound technical basis for optimizing selection, design and implementation of remedies.	***Advanced Predictive Capabilities*** • Develop advanced models that incorporate chemical reactions, complex geologic features, and/or multiphase transport for multiple contaminants (organics, metals and radionuclides) in challenging environments to provide an improved technical basis for selecting and implementing remedies.

Program Area	Technical Risk and Uncertainty	Strategic Initiatives
		• Determine mechanisms and rates of release of contaminants from low porosity/permeability zones. • Develop models that integrate data from various monitoring forms to design long-term monitoring systems
	Treatment and Remediation • In-situ treatment and stabilization technologies provide cost, human health and ecological benefits, but require additional development and demonstration to realize their full potential and to be accepted by the regulatory community. • Ex-situ technologies may be necessary to remove, treat, and dispose of contaminants in certain situations, but current ex-situ treatment technologies may result in high cleanup costs and unacceptable risks to workers.	***Enhanced Remediation Methods*** • Develop, demonstrate and implement advanced in-situ and ex-situ methods which reduce costs, increase effectiveness and reduce risks to human health and the environment. • Improve understanding of in-situ degradation of chlorinated organics and immobilization of radionuclides and metals to facilitate development and use of advanced, cost-effective in-situ technologies and use of natural processes. • Provide the technical basis for use of monitored natural attenuation (MNA) of organics, radionuclides, and metals in the subsurface, including use of MNA in conjunction with other methods (e.g., barrier technology) • Develop safe, cost-effective strategies to treat and remediate legacy materials in historical waste sites, as appropriate.
Deactivation & Decommissioning (D&D) and Facility Engineering	***Characterization*** • Limited techniques for detection, quantification and localization of penetrating radiation, radioactive contamination (e.g. Pu, U, tritium), chemicals (asbestos, beryllium, metals, organics, caustic and acidic solutions, lead paint), and biological contaminants (mold, dead birds and rodents, and animal feces) increase the risk of personnel exposure to hazardous conditions.	***Adapted Technologies for Site-specific and Complex-Wide D&D Applications*** • Develop and deploy improved characterization and monitoring technologies for detecting and quantifying penetrating radiation, radioactive, and biological contaminants. • Develop and deploy improved deactivation, retrieval, size-reduction, and stabilization technologies that provide adequate personal protection and effectively achieve end-state requirements. • Develop and deploy advanced remote and robotic methods to rapidly access and assay facilities to determine optimal D&D approach. • Establish the scientific and technical basis for end-state conditions to satisfy federal, state, and local stakeholders
	Deactivation, Decontamination, and Demolition • Hazardous conditions involving radionuclides, heavy metals, and organic contaminants result in worker safety issues and lead to use of cumbersome personal protective equipment and D&D approaches. • Inadequate historical knowledge of past operations and contamination (and other hazards) drive conservative and costly D&D approaches.	
	Closure • End-state requirements for D&D of process facilities are not adequately defined.	
Integration and Cross-Cutting Initiatives	***Assessing Long-Term Performance*** • Inadequate fundamental understanding of wasteform performance and contaminant release, transport, and transformation processes result in inadequate conceptual models potentially leading to selection and design of non-optimal remedial actions. • Inadequate long-term monitoring and maintenance strategies and technologies to verify cleanup performance could potentially invalidate the selected remedy and escalate cleanup costs.	***Enhanced Long-Term Performance Evaluation and Monitoring*** • Develop increased understanding of long-term wasteform performance integrated with transport of contaminants to support broad remedial action decisions and cost-effective design and operation strategies. • Develop and deploy cost-effective long-term strategies and technologies to monitor closure sites (including soil, groundwater and surface water) with multiple contaminants (organics, metals and radionuclides) to verify integrated long-term cleanup performance.

3.0 ENGINEERING AND TECHNOLOGY PROGRAM MANAGEMENT

To achieve maximum value of the invested resources, DOE-EM manages the program based on these key principles:

- Utilizing sound project management practices;
- Focused development of cost-effective transformational technologies to address high-risk areas to reduce costs and technical uncertainties;
- Integration across all DOE-EM program areas;
- Utilizing existing technologies and information from other programs (e.g., DOE Program Offices, national laboratories, and other Federal Agencies) to the extent practical;
- Self assessment using the best available resources (including the ongoing NAS study which will provide strategic advice to DOE-EM, and structured External Technical Reviews) to identify technology needs and issues and to develop programs to address these risks; and
- Tracking/trending of progress through disciplined performance measures.

These principles provide the foundation for organizing and managing the ***DOE-EM Engineering & Technology Program.***

A successful applied technology and engineering program for DOE-EM will be comprised of programs designated as 'technology-pull' (i.e., driven by project needs) and 'technology push' (i.e., driven by insertion of technologies that are better, faster, or cheaper than the baseline technology).

The risks and initiatives outlined above provide a summary of the technical issues currently facing DOE-EM. Resources to address these needs are provided by a variety of means including both direct site- or project-supported technology development and Headquarters supported technical support and technology development.

In order to provide effective integration and operation of the site projects and Headquarters activities, DOE-EM utilizes an iterative process, schematically shown in Figure 1, for ensuring that resources are provided to address the most pressing technology risk and those that provide the biggest 'return on investment' across the DOE-EM mission areas.

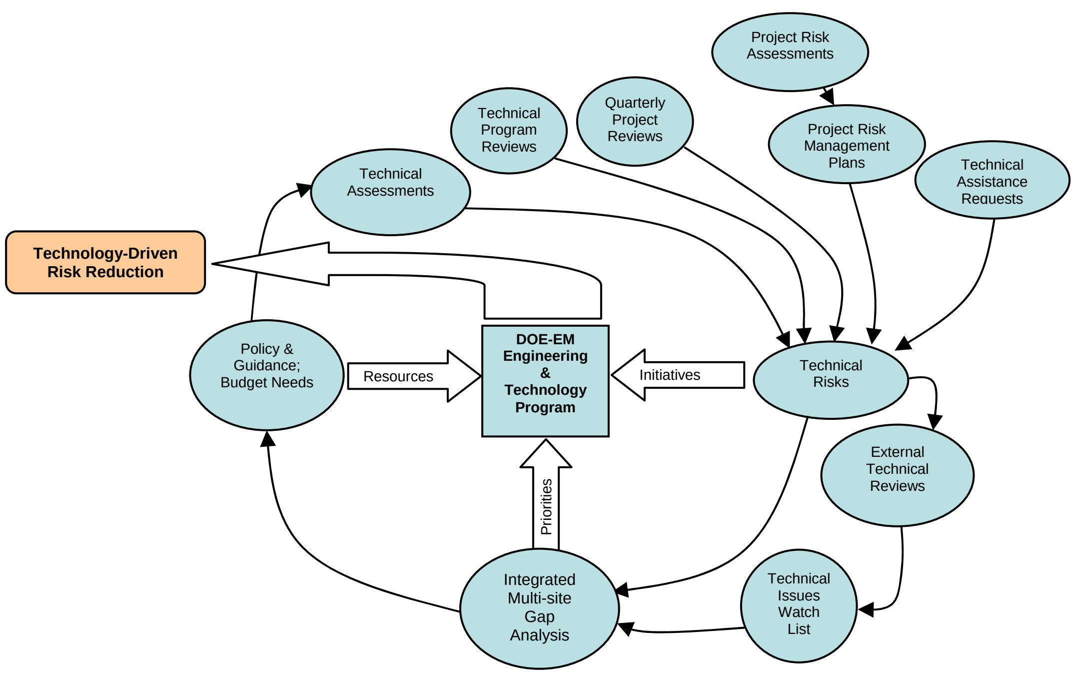

Figure 1 – DOE-EM Engineering & Technology Program Integration

The iterative process depicted in Figure 1 is essential given the reality that many of the projects being managed by DOE-EM are essentially 'first-of-a-kind.' It is anticipated that as the projects execute their assigned functions, additional strategic initiatives may be identified.

In order to ensure that the above principles are applied in a consistent and effective manner, DOE-EM will designate an Initiative Manager for each initiative. The Initiative Manager will develop additional details for each initiative that will include:

- The technical scope of the initiative,
- The schedule for the engineering and technology activities, and
- The point at which the technologies developed will be inserted into the DOE-EM cleanup projects.

The description of each strategic initiative is detailed in Tables 2.1-2.4, and includes background information that more fully explains the risk or uncertainty, a description of the initiative, and the outcomes and anticipated benefits of carrying out the initiative.

The Initiative Manager will be responsible for establishing effective communications among all those involved. In general, this will include workshops, technical exchanges, updates on progress, periodic reviews, and dissemination of lessons learned. The Initiative Manager will also be responsible for developing the technical projects for each initiative, selecting performers, and monitoring their work.

DOE-EM will be assisted in carrying out the ***Program*** by the Savannah River National Laboratory (SRNL). As DOE-EM's Corporate Laboratory, SRNL will pull together teams from the other national laboratories (Idaho National Laboratory (INL), Oak Ridge National Laboratory (ORNL), and Pacific Northwest National Laboratory (PNNL)), the DOE-EM directed programs, and others to provide support to DOE-EM. These 'communities of practice' will function as centers for the purpose of resolving the risks presented in this Roadmap. The initial efforts are planned to be directed toward integrating engineering and technology efforts associated with:

- Tank Cleaning and Closure,
- Long-Term Waste Form Performance Assessment and Analysis,
- Sustainable Groundwater and Soil Solutions, and
- D&D Technology Development and Deployment.

SRNL has also been directed to form a *Technology Integration Office* that will organize and coordinate these centers. SRNL will also assist DOE-EM in integrating the activities of other organizations (e.g., DOE's Office of Science) with DOE-EM's initiatives.

4.0 CONCLUSIONS

This Roadmap presents an integrated approach to reducing the technical risks and uncertainties facing the Department of Energy's Office of Environmental Management in carrying out its cleanup mission, in a manner consistent with its disciplined approach to project management. The risks include challenges in waste processing, groundwater and soil remediation, and deactivation and decommissioning. The ***DOE-EM Engineering & Technology Program*** has been developed to address these risks, and will use applied research and engineering to improve technologies and processes at DOE sites across the country.

The ***Program*** consists of ten strategic initiatives addressing these risks. For each initiative, the anticipated outcomes and benefits have been described in the Roadmap. For each initiative, an Initiative Manager will be named who will develop additional details on the scope and schedule of the initiative.

Focused, applied engineering and technology development has played a crucial role in many of DOE-EM's past successes. The initiatives described here are aimed to play the same role, and thus to ensure DOE-EM's success in paying off the mortgage of the Cold War – achieving the safe and compliant disposition of legacy wastes from defense nuclear applications.

Table 2.1 – Waste Processing Strategic Initiatives

Background Description	Initiative Details	Outcome and Benefits
Strategic Initiative: Improved Waste Storage Technology		
Most HLW in the DOE complex is stored in large (approximately 1,000,000 gallon) underground storage tanks. These tanks were built from the 1940's through the 1970's and are constructed of carbon steel. Current operations are limited by available tank space. Engineering options to expand the waste storage capacity are limited by tank conditions (e.g., previous leak sites, stress allowances, etc.). Limitations in the understanding of flammable gas retention in HLW tanks have often led to very conservative limits on storage and significant costs in ventilation upgrades. Improvements in storage conditions could have significant benefits on future waste processing operations by allowing additional space for process flexibility, enhancing characterization of the stored wastes to improve processing predictions, and increasing the surety of future safe operations. Also, with waste being stored for a long time in aged tanks, the integrity of these tanks must be maintained to allow future safe retrieval operations. This work will benefit both the Hanford and Savannah River sites.	***Develop Improved Monitors to Enhance Waste Storage*** – Develop advanced technology monitors to improve detection and measurement of the solids-liquid interface in waste tanks for more precise control of tank level.	Install advanced monitors that provide increased certainty in tank levels and solids-liquid interfaces. This additional precision will increase storage capacity by eliminating conservatisms applied to account for the limitations of current waste monitoring technologies.
	Improve Tank Integrity Assessment – Develop a more complete understanding of corrosion mechanisms for different regions in the tank annulus or exterior and within the tanks (vapor phase, liquid-line, etc.) to reduce the conservatism in existing tank chemistry controls and guide efficient non-destructive testing programs to ensure tank integrity. All modes of tank failure and potential leakage will be considered.	Reduce the conservatism of existing corrosion control standards through an improved understanding of degradation processes while maintaining adequate safety and integrity. Implement more effective methods to characterize larger areas of tank walls for more frequent and detailed determination of tank integrity. This will reduce the costly additions of chemicals to the tanks while maintaining the same level of assurance of integrity.
	Improve Understanding of Waste Chemistry and Behavior – Develop increased understanding of waste chemistry in order to quantify flammable gas (primarily hydrogen) generation mechanisms and behavior to eliminate conservative constraints on processing and to minimize required tank ventilation upgrades.	Implement less conservative constraints on flammable gas control to provide increased storage capacity, minimize expensive ventilation upgrades, and remove operational constraints.
Strategic Initiative: Reliable and Efficient Waste Retrieval Technologies		
One of the objectives of the tank cleanup program is to retrieve waste to the maximum extent practical for subsequent processing and treatment. Current waste retrieval technologies for removing bulk wastes are generally not suited for removing small amounts of residual waste, especially from tanks containing numerous obstructions. Complications include difficult to remove waste deposits, limited accessibility, in-tank debris, etc. Inhomogeneous (i.e., different size, shape, consistency) bulk waste retrieval could leave waste that is not acceptable for processing due to size or composition. Additionally, a number of tanks are known or suspected to have leaked in the past. This may limit the use of current technologies that require significant water additions. Improved mechanical and chemical retrieval is needed.	***Develop a Suite of Residual Waste Removal Technologies*** – Develop a 'toolbox' of technology solutions to remove small quantities of liquid and solids remaining in tanks after bulk waste removal operations are completed. The developed technologies will remove radioactive material on the internal surfaces (walls, cooling coils, and other internal obstructions) and agglomerated materials that resist physical removal. Develop engineering and technology solutions for recovery from off-normal events such as piping plugging.	Implement a suite of demonstrated retrieval technologies and engineered solutions that could be deployed for project use with limited modification.
	Develop Options for Chemical Cleaning – Develop a technology base to perform chemical cleaning as required following bulk and residual waste removal. Developed technologies will be suitable for deployment in tanks with significant obstructions and limitations on liquid addition.	Implement advanced cleaning protocols that effectively remove residual materials while maintaining tank integrity required during closure operations. This will reduce the radioactive source term in tanks, potentially enabling more cost-effective closure and long-term monitoring techniques.

Table 2.1 – Waste Processing Strategic Initiatives (continued)

Background Description	Initiative Details	Outcome and Benefits
Strategic Initiative: Enhanced Tank Closure Processes		
No bulk or specialized retrieval operation will economically remove all of the waste from underground storage tanks. Because these residual limits play such an important role in the tank closure process, accurate and reliable methods for measuring the quantity of residuals (volume) are of paramount importance. The size and geometry of tanks, limited points of access and obstructions (cooling coils and other tank components) make accurate residual waste measurements very difficult. New techniques and/or technologies are necessary to enhance the ability to make accurate and reliable measurements. Waste classification, either under DOE Order 435.1 or Section 3116 of the NDAA, is an integral part of the closure process at all sites and requires immobilization of the low-level radioactive waste residues in the tanks. Cementitious materials (grout) are used worldwide to immobilize low-level waste and it is the choice of DOE for tank closure. These materials are also planned for closure of ancillary equipment (such as pumps, valve boxes, and underground transfer lines).	***Improve Residual Tank Waste Characterization and Stabilization*** – Develop sampling and analysis methods that accurately assess the quantity and activity of residual tank waste in preparation for tank closure. Develop improved materials (i.e., grouts) that efficiently stabilize the residual tank waste and provide long-term stabilization required for on-site disposal and closure. This work will build upon the lessons-learned from previous tank closures, technical exchanges and workshops, and ongoing applied research activities.	Implement enhanced technology methods for residual activity determination. Utilize improved materials for stabilization that efficiently provide long-term stability required by closure performance assessments.
	Develop Materials and Technologies to Close Ancillary Systems – Develop technologies to characterize residual waste in ancillary equipment in order to determine effective closure strategies for these systems. Develop closure materials (i.e., highly flowable grouts) which can be utilized for closing long underground transfer lines and other difficult-to-access ancillary systems.	Implement advanced technologies capable of assessing residual activity in ancillary systems and transfer lines and closure materials suitable for difficult geometries.
	Perform Integrated Cleaning, Closure, and Capping Demonstrations – Develop engineering and technology demonstrations to evaluate all aspects of tank closure, including options for disposal cap development. These could be used as a test platform for determining long-term performance characteristics and monitoring strategies.	Complete closure demonstrations at multiple sites to guide future tank closure projects. These demonstrations will integrate tank closure actions with requirements for long-term monitoring of soil and groundwater.
Strategic Initiative: Next-Generation Pretreatment Solutions		
Pretreatment technologies will be developed to enhance and improve baseline technologies, explore pretreatment alternatives, and to add parallel processing options so that waste processing schedules can be shortened or started earlier and technical risks involving processing pinch points will be reduced. Alternative and enhanced pretreatment options will yield a multi-site benefit. For example, in the current baseline, waste must be removed from tanks at Savannah River and at Hanford, high- and low-activity waste separated in a pretreatment process facility, and then immobilized in other facilities. At-tank processes would enhance separations of solids and liquids and highly radioactive from low-activity components. This would reduce the overall schedule for processing and reduce the life-cycle cost.	***Develop In- or At-Tank Separations Solutions*** – Develop or demonstrate technologies for separating low-level from HLW fractions and removing solids from these solutions as required. Develop tailored process flowsheets for varying tank conditions and compositions.	Demonstrate modular in- or at-tank technologies as alternatives to costly pretreatment facilities and processes. Implement alternatives as appropriate.
	Develop Improved Methods for Waste Separation – Develop engineered solutions that more effectively separate inert materials and low-level waste from HLW such that only the HLW fraction is stabilized for geological disposal. This would include removal of large amounts of aluminum from HLW at Savannah River and large quantities of chromium from HLW at Hanford.	Implement engineered process solutions to minimize waste fractions being processed as HLW to reduce stabilized waste forms requiring geological disposal.

Table 2.1 – Waste Processing Strategic Initiatives (continued)

Background Description	Initiative Details	Outcome and Benefits
Strategic Initiative: Enhanced Stabilization Technologies		
This initiative would improve the campaign to vitrify waste through applied research to improve all aspects of the vitrification process. Improvements have a multi-site benefit and yield significant savings. Alternative or improved melter designs may enable operations at elevated temperatures and higher throughput in the same plant footprint. Improved glass formulations that allow a higher waste loading would reduce the number of waste packages and improve throughput, both of which have significant benefits. Incremental gains could benefit current processing activities, while exploratory work on future wastes would also be used in planning activities. An overall loading improvement of a few percent could shorten the waste processing schedule by over a year and potentially save over $1 billion. Additionally, there are some wastes that will require extensive pretreatment for processing at a large vitrification facility. For these wastes, supplemental treatment operations are needed.	***Develop Next-Generation Melter Technology*** – Develop alternative technologies for melter operation that permit increased waste loading and/or higher melter throughput. In current planning, the estimated melter lifetime is approximately five years before replacement. Improved melter designs will provide improved operations, longer melter life, and increased loading (thereby reducing the number of HLW canisters). This work will utilize results from the DOE-EM International Program and other DOE-EM investments to improve throughput and waste loading through advanced melter designs.	Install next-generation melters at waste processing facilities to replace current joule-heated melters and improve operations at the Defense Waste Processing Facility and the Waste Treatment Plant.
	Develop Advanced Glass Formulations – Develop improvements in the existing vitrification processes that allow increased waste loading and greater throughput. This, in turn, would reduce the life cycle of waste processing operations and/or the number of HLW canisters that must be disposed in a deep geological repository. Refine the predictive models used for operation of the waste processing facilities and integrating pretreatment and stabilization specifications to provide enhanced operational control and improved life-cycle management. This work will utilize the investments being made by National Laboratories and academia aimed at improving existing process operations.	Incorporate improved glass formulations into existing processing operations with minimal in-plant testing or verification. Minor improvements in waste loading (on the order of a few percent) or reductions in cycle time (on the order of a few hours per canister produced) have been demonstrated to yield significant cost savings.
	Develop Supplemental Treatment Processes - Develop bulk vitrification, steam reforming, or other supplemental treatment processes required to meet project needs. This work will build on the Demonstration Bulk Vitrification System (DBVS) project at the Hanford site and the steam reforming process development being performed to support the Sodium Bearing Waste Treatment project at the Idaho site.	Complete demonstrations of supplemental treatment technologies and deploy those technologies as needed to support project operations.

Table 2.2 – Groundwater and Soil Remediation Strategic Initiatives

Background Description	Initiative Details	Outcome and Benefits
Strategic Initiative: Improved Sampling and Characterization Strategies		
Cost effective characterization of subsurface contaminants beneath or in proximity to operating facilities and subsurface interferences is a major challenge throughout the DOE Complex. Expensive and time-consuming drilling techniques provide only point source measurements and potentially leave large gaps in subsurface contaminant plume delineation. This can result in the development of inappropriate or inadequate cleanup strategies and require that sites be revisited following completion of cleanup efforts.	***Develop Next-Generation Characterization Technologies and Strategies*** - This initiative supports the development of next-generation subsurface sampling and characterization technologies and strategies. The focus will be characterization of multiple contaminants (organics, metals and radionuclides) in challenging environments (e.g., around subsurface interferences, at great depth and in low porosity/permeability zones). This may include sentinel or biomarker approaches that are direct indicators of exposure and/or effect of multiple contaminants. Basic and applied research will provide a better understanding of contaminant subsurface behavior (i.e., mobilization, transformation, transport and fate) to enhance DOE's ability to select, design and implement safe, cost-effective remedies. The initiative will utilize, as appropriate, information developed by earlier DOE and Department of Defense research and development efforts to minimize the need for extensive point source measurements.	Develop, demonstrate and deploy cost-effective sampling and characterization technologies that adequately characterize subsurface plumes and provide a sound technical basis for selecting, designing and deploying remedies. Gain Federal and State regulatory acceptance of next-generation sampling and characterization technologies and strategies. Utilize national basic and applied science programs and past investments.
Strategic Initiative: Advanced Predictive Capabilities		
Large inventories of radionuclides, metals, and chlorinated organics are dispersed in 1.8 billion cubic meters of contaminated soil and groundwater at DOE sites. For complex sites, current models do not adequately address critical parameters such as waste physical and chemical characteristics, the biological and geochemical nature of the subsurface, site geologic heterogeneity, and subsurface phenomena (oxidation / reduction, adsorption, and precipitation which can be expressed as chemical reactions in advanced numerical models to improve predictive capabilities). Improved understanding of subsurface phenomena and advanced models are needed to provide a sound basis for selection, design and implementation of remedies and long-term monitoring.	***Develop Advanced Fate and Transport Models*** – Basic and applied research (including the results of previous DOE and Department of Defense research and development efforts) will be utilized to gain an improved understanding of subsurface conditions and phenomena, and their impact of the mobilization, transport, transformation and fate of contaminants of concern at DOE sites. Based on this improved understanding of the subsurface the initiative will develop and demonstrate advanced models needed to optimize characterization, reliably inform remedial decisions, and optimize site monitoring.	Advanced models, which address complex subsurface characteristics and phenomena, will provide an improved, more certain technical basis for selection, design, implementation and regulatory acceptance of remedial actions at Hanford, Idaho, Oak Ridge, Paducah, Portsmouth, Savannah River and other sites.
	Develop Integrated Methods for Long-Term Monitoring – This initiative will develop and demonstrate advanced models that support non-point monitoring and integrate data from various monitoring forms (e.g., groundwater, remote, soil, plant, river system, etc) to provide an alternative to the current approach to long-term monitoring (frequent single point, down-hole sampling from a large number of wells), which is projected to be one of the largest cost factors associated with remedial projects. The alternative approach will be cost-effective, diverse, and robust to provide multiple lines of evidence for protection of human health and the environment.	

Table 2.2 – Groundwater and Soil Remediation Strategic Initiatives (continued)

Background Description	Initiative Details	Outcome and Benefits
Strategic Initiative: Enhanced Remediation Methods		
Currently, DOE employs remediation technologies that rely heavily on expensive ex-situ methods (i.e., pump and treat) or limited in-situ (i.e., steam stripping) techniques. Cost-effective in-situ technologies need to be developed and demonstrated. As our knowledge and understanding of the mechanisms for fate and transport due to natural system processes improves, sustainable, in-situ approaches can be designed. These approaches will better balance in-situ technology with enhanced and natural attenuation to allow maximum use of natural system capacity and processes. Where in-situ methods are not practical, improved ex-situ techniques are required. Historical waste sites present unique challenges to retrieve, treat, and remediate the variety of wastes at these sites. These include contaminated soils, buried drums, and other materials posing an environmental risk.	***Develop Advanced Remediation Methods*** – The initiative will develop improved in-situ remediation technologies that reduce costs, increase effectiveness, and better protect workers and the environment. Improvements will include development and demonstration of passive systems such as permeable reactive barriers, nanoparticle technology, bioremediation, phytoremediation, and long-term barriers. Improvements will also include development of technical basis for using monitored natural or enhanced attenuation. These approaches are both sustainable and cost-effective. This initiative will also address retrieval of buried waste and other materials where necessary.	Deploy advanced cost-effective and safe remediation methods and strategies that target the primary contaminants that drive performance assessments and environmental impact.

Table 2.3 – Deactivation & Decommissioning (D&D) and Facility Engineering Strategic Initiatives

Background Description	Initiative Details	Outcome and Benefits
Strategic Initiative: Adapted Technologies for Site-specific and-Complex Wide D&D Applications		
Focus on innovative application and timely insertion of existing commercially available technologies, processes and hardware systems to address the identified D&D risks and challenges. This is accomplished by adapting, modifying (for site-specific requirements), optimizing (for assured safety, better efficiency and lower cost) and demonstrating existing technologies and hardware to produce sufficient technical data and operating parameters to allow the site D&D operators to insert these technologies into their baseline operation with confidence. The initiative stresses the buy-before-make approach in the acquisition of improved technology. Developing enabling novel technologies, when justified by the site-needs and deployment schedule, will be considered on a case-by-case basis. This initiative supports development of an informed facility D&D strategy; enhanced verifiability of the efficacy of D&D operations; increased productivity and personnel safety of D&D operation; and facilitation of acceptable facility end-state.	***Characterization - Improve Characterization and Monitoring Technologies for Detection and Quantification of Penetrating Radiation, Radioactive, and Bio-Contaminants –*** Develop: portable real-time Beryllium characterization and monitoring devices for facilities and equipment; regulator-approved field characterization technologies and methods that would facilitate quicker decision-making regarding contaminant removal efforts for concrete; hot cell radionuclide inventory characterization technology; and technology for non-destructive characterization of waste containing high concentrations of Technetium-99 or other radioisotopes that are difficult to characterize by this method.	Deploy improved characterization and monitoring technology into the D&D baseline operations at applicable DOE-EM sites. Facilitate the development of effective facility D&D strategies based on defensible analysis and evaluation of facility conditions and hazards.
	Deactivation - Enhance D&D Technologies and Equipment – Develop: pool liner integrity monitoring technology (Oak Ridge Research Reactor); technology to treat sodium contaminated process components and equipment; improved contaminant (Plutonium-238) control methods or fixatives for facility deactivation and/or in-situ closure (F-Area Material Storage Facility at Savannah River); improved concrete scrabbling methods; and improved personnel protective technologies.	Deploy advanced technologies and processes allowing for safe deactivation of facilities.
	Decontamination - Advance Remote and Robotic Systems to Access and Assess Highly Contaminated and Unsafe Old Facilities – Develop: remote sampling equipment for characterization/analysis of tank wall and bottom residue; package or skid mounted treatment units for treatment of inert status chemicals or radioactive components generated during facility deactivation or demolition; systems for the separation of massive equipment laden with radioactive material; and improved personnel protective clothing technologies.	Deploy advanced equipment that effectively accesses, characterizes unsafe facilities, and removes large and complex structures with limited operator involvement.
	Demolition - Improve Containment, Disassembling, Size-Reduction and Demolition Technologies – Develop: non-intrusive tools to detect and locate energized electrical lines or conduits in soils and in concrete; improved methods for dust suppression during demolition (Savannah River); underwater cutting, retrieval and packaging techniques (Oak Ridge); and improved methods for demolition of off-gas stack and associated facilities (Oak Ridge).	Deploy enabling demolition technologies and improved methods/processes for better suppression and containment of dust and contaminants during facility demolition
	Closure - Develop Technology for Informed End-State Strategies – Develop: canyon disposition (in-situ decommissioning) modeling and in-situ removal and stabilization of contaminants; the Permeable Adsorptive Liner (PAL) technology for onsite disposal of contaminated D&D construction debris, facility waste, small discrete waste sites, and pipelines; technology for surveying large area radiological and hazardous materials and real-time processing of survey data processing for end-state verification (PPPO); and stand-alone powered environmental samplers.	Complete demonstrations of targeted D&D operations to demonstrate effective achievement of required end-state conditions

Table 2.4 – Integration and Cross-Cutting Initiatives

Background Description	Initiative Details	Outcome and Benefits
Strategic Initiative: Enhanced Long-Term Performance Evaluation and Monitoring		
Technical challenges exist in the assessment of uncertainties associated with waste processing, soil and groundwater remediation, and D&D approaches. Evaluating the performance of the integrated waste closure unit requires extrapolation of short-term performance data to extended periods of time. Current materials (i.e., glass, grout, etc.) are commonly used to immobilize high-level and low-level radioactive wastes. Storage for extended periods of time (100’s or 1,000’s of years) is difficult to predict and leads to uncertainties in the long-term performance of the closure unit. Additional data and integrated approaches are needed to provide the necessary understanding of the behavior of the closure unit over the long-term so that appropriate strategies can be selected and so that performance assessments will be based on improved predictive capabilities. Cost-effective approaches are needed to monitor residual contamination in soil and groundwater and to verify remedial performance over many years, in some instances for decades or centuries.	***Develop Improved Understanding of Long-Term Performance*** – Develop programs and approaches (including accelerated test protocols) to improve understanding of long-term wasteform performance. Integrate the information gained with improved understanding of contaminant transport to enhance long-term risk assessment and predictive modeling capabilities.	Utilize advanced predictive models and other tools in site and project risk assessments and performance evaluations to better define closure strategies and increase stakeholder confidence. Develop improved understanding of long-term wasteform performance and radionuclide transport.
	Develop Enhanced Long-Term Monitoring Strategies – Reduce reliance on expensive point source measurement techniques by implementing advanced monitoring capabilities and strategies (e.g., flux, surrogate, and environmental sentinel measurements). Identify appropriate indicators for monitored natural attenuation for soil and groundwater plumes. Integrate these enhancements with long-term performance prediction to validate closure approach.	Implement cost-effective, advanced monitoring capabilities and strategies for soil and groundwater cleanup. Deploy innovative in-situ assessment techniques that evaluate long-term wasteform performance integrated with performance assessment predictions.